Quarterly Technical Summary

Advanced Electronic Technology

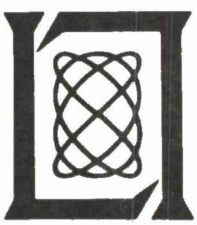
15 February 1972

Prepared under Electronic Systems Division Contract F19628-70-C-0230 by

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts



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AIR FORCE 37360 23 MARCH 1972 - 725

The work reported in this document was performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology, with the support of the Department of the Air Force under Contract F19628-70-C-0230.

INTRODUCTION

This Quarterly Technical Summary covers the period 1 November 1971 through 31 January 1972. It consolidates the reports of Division 2 (Data Systems) and Division 8 (Solid State) on the Advanced Electronic Technology Program.

Accepted for the Air Force
Joseph R. Waterman, Lt. Col., USAF
Chief, Lincoln Laboratory Project Office

CONTENTS

DATA SYSTEMS
DIVISION 2

INTRODUCTION

This section of the report reviews progress during the period 1 November 1971 through 31 January 1972 for the Advanced Electronic Technology Program of Division 2. Separate progress reports on Graphics, Propagation Studies, Seismic Discrimination and the Educational Technology Program describe other work in the Division.

M. A. Herlin
Acting Head, Division 2

I. L. Lebow
Associate Head

DIGITAL COMPUTERS
GROUP 23

I. INTEGRATED CIRCUIT PROCESSING

A. Transistor Fabrication

A number of runs with boron nitride sources indicate that they are satisfactory for base diffusions. Spin-on phosphorous emitter sources gave wide scatter in beta. Doped oxides pyrolytically deposited by the new reactor seem satisfactory sources for washed emitters based on several diode runs.

B. Computer Modeling

The computer model has been tested for simple structures and seems to give coherent results. The output is being modified to provide resistivity directly so that quick correlation with actual diffusion data will be available. A complex structure is now being evaluated for comparison with a model from another organization.

C. Metalization

Al-Si alloy deposition has been attempted from tungsten filaments with 4% Si content, and RF induction heated crucibles using 50% Si content in aluminum. Contamination and adhesion problems were encountered with the crucible sources. At very high deposition rates (1000 Å/sec), the filament source metal is smooth, apparently contamination-free, contains between 0.5% to 1% Si and adheres well.

The 6-wafer metalization fixture has been checked out and will be installed upon completion of the filament experiments.

D. Photolithography Techniques

Installation of a supplementary cold trap, changes in the vacuum system operation, and improvements in wafer cleaning have produced good metal-to-oxide adhesion.

Resist-to-metal adhesion was marginal for the etchant used. Modification of the etchant has eliminated the resist breakdown that resulted in the metal's peeling off during etching.

Slots 0.08 mil wide are being routinely etched in oxide. A new type of photoresist is being used for all types of oxide etching; it is thinner, produces slightly better edge definition, and reduces undercut – especially in phosphorous glass. It does not adhere to Si-Al as well as KTFR, and it is not being used for metal etching.

E. Photo-Encapsulated Wiring (PEW)

Poor etchability of via-hole walls compared with array dielectric-layer surfaces is attributed to the fact that the resin in the vias is exposed to air during most of the cure cycle. This oxygen exposure inhibits the curing process. In contrast, the array surface, initially covered with mylar, is less exposed to the oxygen and is more completely cured. This has been verified by the excellent results obtained by curing arrays under nitrogen.

The previously required slurry abrading of via holes is no longer necessary in order to obtain good etching and sensitization of all array surfaces, and uniform deposits of electroless nickel.

Chip-mounting and array-exposure jigs have been modified and upgraded to accommodate larger arrays of integrated circuit chips. Currently, a 20-chip memory array is being fabricated. Full-size arrays of dummy chips (metalization only, on silicon) are being assembled to check procedures. Anticipated difficulties with array flatness and pattern registration due to resin shrinkage during cure have proved minimal or nonexistent.

F. Metalization of Chip Aluminum

Procedures for nickeling aluminum chip pads have been modified to eliminate materials containing sodium and potassium and to overcome "corrosion cell" action which inhibits electroless nickel deposition on chip pads connected directly to the silicon p-substrate.

II. INTEGRATED CIRCUIT APPLICATIONS

A. Semiconductor Memory Array Using PEW

A simulation of the circuit used in the 1000 semiconductor memory which will utilize PEW has been evaluated for heat transfer from the chip to the heat sink. The thermal resistance has been measured to be approximately 12°C/W, a factor of 2 better than the calculated value.

One of the above samples has been in an oven, at 100°C, since mid-November. There has been no change observed in the transistor characteristics.

B. Analog-to-Digital Converter Analysis

A study to determine the best computer circuit-analysis program for use in the design of high-speed switching circuits with bipolar devices showed that the version of CIRCUS available on the Laboratory's IBM 360/67 is most appropriate for experimental analyses involving short runs. Extensive analyses can be done more economically with commercially available programs.

III. SEMICONDUCTOR TESTING AND DESIGN

A. Memory System Tester

The test equipment for evaluating the completed PEW memory system and its mock-up is finished and working properly. A functional tester for memory chips has also been built.

All the required memory chips have been obtained; however, the decoder and batch chips are currently unavailable from the vendor.

B. Semiconductor Testing

Probing and testing of semiconductor wafers are now being performed as a routine task, using the Electroglas automatic prober, special-purpose parameter-measuring equipment, the TIC terminal, and the TX-2 computer. The various support programs which control the prober, digital voltmeter, and digital-to-analog converter; which accumulate and store the resulting test data; and which prepare wafer test result maps and distribution plots are all operating satisfactorily.

Approximately 20 prober-passes on wafers containing 100 to 400 devices are being made each week. Measurements have been made of breakdown voltages, leakage currents, and beta on both shallow and deep-diffused transistors; and of contact resistance of both Al and Al-Si alloy metalization on Si.

Improved measuring equipment is being built which will allow several device parameters to be measured while the probes are in contact during a single prober pass. Also being studied are improved test control programs which will reduce the load on the TX-2 computer and speed up testing during periods of heavy time-shared usage of TX-2.

C. Noncontact Current Probe

Connecting the integrated circuit current probe to the SEL computer through an A/D converter provides the ability to sense very small fields ($\approx 10^{-6}$ Oe) with the aid of computer averaging.

D. Computer-Aided Logic Design

An intensive evaluation of an on-line logic drawing and simulation computer system (OLLS) at the C. S. Draper Laboratory at M.I.T. has led to initiating a design of a similar system using storage scope displays on the TX-2.

E. Double Raster Display

Backpanel wiring and PC boards for the Double Raster Display and C4 processor are over 90 percent completed. Boards are gradually being populated with ICs; hardware should be ready for debugging by the next report period.

COMPUTER SYSTEMS
GROUP 28

Early in this quarter, International Business Machines installed its Systems Measurement Instrument (SMI) on Lincoln's IBM 360/67 for a week of data collection activity. The SMI recorded hardware performance at a number of points jointly established by IBM and Lincoln personnel. The value of the information produced was in confirming intuitive feelings about system behavior and, more importantly, verifying the accuracy of the software measuring tools previously reported.

A procedure for dynamically recording load parameters on the CP/CMS time-sharing system is now in regular daily operation. Every 10 sec it samples the value of 30 counter or state variables and, after 16 samples are obtained, writes this information to disk. At a later time, the data are retrieved and divided into classes according to the number of active users. The latter indicates the number of virtual machines which are requesting service from the CPU or have I/O (other than terminal I/O) outstanding. For each class, the minimum and maximum values for each variable are determined. In addition, for state variables (such as the number of drum slots in use) the average value for each class is computed, and for counter variables (such as the number of drum channel I/O operations) the average of the incremental value between samples is computed. A report is then produced which summarizes these data for each class. To obtain an overall characteristic for a day, the summary data are weighed by the number of active users to produce a representative average, minimum, and maximum for each counter or state variable. This procedure eliminates sample points which occur infrequently and emphasizes frequent occurrences. The representative value for each variable is then plotted for each day so that trends in system load or system performance can be observed.

In conjunction with the ability to record system load parameters, a technique has been developed for artificially and uniformly loading the system. During a test period, virtual machines are automatically logged in and initialized to run a predefined program which puts a known load on the system. This permits changes in system algorithms to be correlated with system behavior under controlled conditions. For certain kinds of experiments and debugging, this technique is very valuable. At the same time, it is quite clear that this is only one facet of such work and that the picture is not complete without the typical random activity of many users.

Two significant improvements to the paging mechanism were made. First was the outright release of pages which are known to be of no further use. In addition to reducing unnecessary traffic on the drum channel, there was the important space saving which all but ended overflow to the slower swapping disk. Without the latter, an increase in the number of users would either have required another drum or would have been severely limited by the disk performance. The second improvement was a change in the algorithm by which CP writes pages to the swapping device. The new scheme sorts these output requests on the basis of their relative position, allowing several requests to be chained together to take full advantage of the rotational position of the drum during a single revolution.

To compare systems with and without these changes, a heavy load was placed on each system using the artificial load technique described above. Paging characteristics were then compared, demonstrating that the changes permitted an increase in the paging capacity of the system with a concomitant increase in virtual CPU time. Operation with these changes under a uniform load shows that drum pages used are down by 20 percent and that the drum channel I/O rate is up 10 percent. These and other changes have enabled the time-sharing system to service 50 simultaneous users with a typically short or nonexistent waiting line. With the increase in the number of users, there has been an increase of approximately 10 percent in the throughput attainable from the system.

Release 20.1 of the batch processing system OS/360 became operational during this quarter. It is now stable and reliable. Data on the performance of this new release were collected by the SMI. Although it indicates nearly 75-percent problem state, there is some question that changes in scheduling might improve the degree of I/O overlap and provide greater efficiency.

SOLID STATE
DIVISION 8

INTRODUCTION

This section summarizes the work of Division 8 from 1 November 1971 through 31 January 1972. A more detailed presentation is covered by the Solid State Research Report for the same period.

A. L. McWhorter
Head, Division 8

P. E. Tannenwald
Associate Head

DIVISION 8 REPORTS ON ADVANCED ELECTRONIC TECHNOLOGY

15 November 1971 through 15 February 1972

PUBLISHED REPORTS

Journal Articles*

JA No.			
3775	Partial Pressures in the Cd-Te and Zn-Te Systems	R. F. Brebrick	J. Electrochem. Soc. 118, 2014 (1971)
3786	Luminescence of EuTe and Other Europium Chalcogenides	D. Hulin† J. Hanus† C. B. A La Guillaume† T. B. Reed	Solid State Commun. 8, 1525 (1970)
3797	Conductivity Studies in Europium Oxide	M. R. Oliver J. O. Dimmock A. L. McWhorter T. B. Reed	Phys. Rev. B 5, 1078 (1972)
3885	Accurate X-Ray Diffraction Measurements at High Pressures: Volume Compression of TiO_x	M. D. Banus M. C. Lavine	High Temperatures-High Pressures 2, 671 (1970), DDC AD-736303
3887	High Pressure Synthesis of (ABX_3) $(AX)_n$ Compounds	J. A. Kafalas J. M. Longo†	J. Solid State Chem. 4, 55 (1972)
3894	High Apparent Mobility in Inhomogeneous Semiconductors	C. M. Wolfe G. E. Stillman J. A. Rossi	J. Electrochem. Soc. 119, 250 (1972)
3899	Exciton Bands in Antiferromagnetic Cr_2O_3	R. M. Macfarlane† J. W. Allen	Phys. Rev. B 4, 3054 (1971)
3908	Spin-Wave Theory of Two-Magnon Raman Scattering in a Two-Dimensional Antiferromagnet	S. R. Chinn R. W. Davies H. J. Zeiger	Phys. Rev. B 4, 4017 (1971)
3913A	Precision Verification of Effective Mass Theory for Shallow Donors in GaAs	G. E. Stillman D. M. Larsen C. M. Wolfe R. C. Brandt†	Solid State Commun. 9, 2245 (1971)
3917	Comment on the Magnetic Properties of Several Indium Thiospinels	J. B. Goodenough	J. Solid State Chem. 4, 292 (1972)

* Reprints available.

† Author not at Lincoln Laboratory.

JA No.

3940	Raman Scattering from Europium Chalcogenides	R. K. Ray* J. C. Tsang* M. S. Dresselhaus R. L. Aggarwal* T. B. Reed	Phys. Letters 37A, 129 (1971)
3948	Optical Observation of Stress-Induced Spin Flop in Cr_2O_3	J. W. Allen	Phys. Rev. Letters 27, 1526 (1971)
3965	Optically Pumped Room-Temperature $In_xGa_{1-x}As$ Lasers	J. A. Rossi S. R. Chinn A. Mooradian	Appl. Phys. Letters 20, 84 (1972)
3975	Near-Resonance Spin-Flip Raman Scattering in Indium Antimonide	S. R. J. Brueck A. Mooradian	Phys. Rev. Letters 28, 161 (1972)

Meeting Speeches

MS No.

2964	Magneto-Optical Properties of the Eu-Chalcogenides	J. O. Dimmock	The Physics of Opto-Electronic Materials, W. A. Albers, Jr., Ed. (Plenum, New York, 1971), pp. 255-271
2992	Varied Roles of the Outer d Electrons	J. B. Goodenough	Chap. III in Proceedings of the Robert A. Welch Foundation Conferences on Chemical Research XIV. Solid State Chemistry, Houston, Texas, 9-11 November 1970, W. O. Milligan, Ed. (The Robert A. Welch Foundation, Houston, 1971), p. 75
3067	Polaron Morphologies in Vanadium Oxides	J. B. Goodenough	Conduction in Low-Mobility Materials, N. Klein, D. S. Tannhauser and M. Pollak, Eds. (Taylor & Francis Ltd., London, 1971), p. 87
3144	Materials and Processing Techniques for the Fabrication of High Quality Millimeter Wave Diodes	B. J. Clifton W. T. Lindley R. W. Chick R. A. Cohen	Proc. Third Biennial Cornell Electrical Engineering Conference, Cornell University, Ithaca, 17-19 August 1971, p. 463
3192	Tunable Infrared Lasers and Their Applications	P. L. Kelley E. D. Hinkley A. Mooradian	NEREM Record 13, Pt. 1, 221 (1971)

* Author not at Lincoln Laboratory.

UNPUBLISHED REPORTS

Journal Articles

JA No.			
3857	Comment on "Observation of Nonextremal Fermi Surface Orbits in Bulk Bismuth" – Author's Reply	V. E. Henrich	Accepted by Phys. Rev.
3880	Influence of Atomic Vacancies on the Properties of Transition-Metal Oxides: I. TiO_x and VO_x	J. B. Goodenough	Accepted by Phys. Rev. B
3889	Electrical and Magnetic Properties of 'TiO' and 'VO'	M. D. Banus T. B. Reed A. J. Strauss	Accepted by Phys. Rev. B.
3892	Shubnikov-de Haas Measurements in $Pb_{1-x}Sn_xSe$	J. Melngailis T. C. Harman W. C. Kernan	Accepted by Phys. Rev. B
3900	The Heats of Transformation of the High-Pressure Orthorhombic Modification of Indium Antimonide	A. K. Jena* M. B. Bever* M. D. Banus	Accepted by Met. Trans.
3901	Thermal Brillouin Scattering in Cadmium Sulfide: Velocity and Attenuation of Sound; Acousto-electric Effects	A. S. Pine	Accepted by Phys. Rev. B
3902	Resonance Brillouin Scattering in Cadmium Sulfide	A. S. Pine	Accepted by Phys. Rev. B
3911A	Superconductivity in Cubic and Monoclinic "TiO"	T. B. Reed M. D. Banus M. Sjöstrand* P. H. Keesom*	Accepted by J. Appl. Phys.
3929	Effect of Pressures to 50 kbar on the Magnetic Behavior of MnP	M. D. Banus	Accepted by J. Solid State Chem.
3939	Study of the Optical de Haas-Shubnikov Effect	F. P. Missell* M. S. Dresselhaus	Accepted by Phys. Rev. B
3943A	Non-Γ Donor Levels and Kinetics of Electron Transfer in n-Type CdTe	G. W. Iseler J. A. Kafalas A. J. Strauss H. F. MacMillan* R. H. Bube*	Accepted by Solid State Commun.

* Author not at Lincoln Laboratory.

JA No.			
3957	The Pressure Dependence of the Carrier Concentrations in P-Type Alloys of $Hg_{1-x}CdTe$ at 4.2°K and 77°K	C.T. Elliott* J. Melngailis T.C. Harman J.A. Kafalas W.C. Kernan	Accepted by Phys. Rev.
3967	Sealed Crucible Technique for Thermal Analysis of Volatile Compounds up to 2500°C: Melting Points of EuO, EuS, EuSe and EuTe	T.B. Reed R.E. Fahey A.J. Strauss	Accepted by J. Crystal Growth
3969	Energy Bands in TX_2 Compounds with Pyrite, Marcasite, and Arsenopyrite Structures	J.B. Goodenough	Accepted by J. Solid State Chem.
3971	Raman Scattering in Paratellurite: TeO_2	A.S. Pine G. Dresselhaus	Accepted by Phys. Rev.
3988	Single Crystal Growth of $Hg_{1-x}Cd_xTe$	T.C. Harman	Accepted by J. Electron. Mater.
3992	Preparation and Structure of a Pyrochlore and Perovskite in the $BiRhO_{3+x}$ System	J.M. Longo* P.M. Raccah* J.A. Kafalas J.W. Pierce	Accepted by Mater. Res. Bull.
MS-3090	Influence of Madelung Energy and Covalency on Structure of $A^+B^{5+}O_3$ Compounds	J.A. Kafalas	Accepted by Proc. NBS 5th Materials Research Symposium, Solid State Chemistry, Gaithersburg, Maryland, 18-21 October 1971
MS-3120	Preparation and Structure of a Pyrochlore and Perovskite in the $BiRhO_{3+x}$ System	J.M. Longo* P.M. Raccah J.A. Kafalas J.W. Pierce	

Meeting Speeches†

MS No.			
2951D	Localized vs Itinerant Electrons	J.B. Goodenough	Winter School in Solid State Chemistry, Indian Institute of Technology, Kanpur, India, 22 November – 10 December 1971
3032A	Polaron Self-Energy Effects on Higher Landau Levels in InSb	E.J. Johnson	Seminar, Naval Research Laboratory, Washington, D.C., 31 January 1972
3152B	Acoustical and Optical Activity in Crystals	A.S. Pine	Seminar, Yeshiva University, New York, 9 February 1972

* Author not at Lincoln Laboratory.

† Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

MS No.			
3182	High Spin-Low Spin and Structural Transition in $LaCoO_3$	R. A. Bari	
3186	Recent Topics in Two-Magnon Optical Raman Scattering	S. R. Chinn R. W. Davies H. J. Zeiger	17th Annual Conference on Magnetism and Magnetic Materials, Chicago, 16-19 November 1971
3187	Electronic Raman Scattering in FeF_2	S. R. Chinn H. J. Zeiger	
3231	Elastic Constants, Compressibilities and Debye Temperatures of the Eu-Chalcogenides	Y. Shapira* T. B. Reed	
3222	Energy Bands in Arsenic	R. W. Brodersen G. Dresselhaus M. S. Dresselhaus	
3223	Optical Properties of Graphite	L. G. Johnson G. Dresselhaus	
3224	Reflectivity and Optical Constants of SnO_2	C. L. Rieck M. S. Dresselhaus W. Scouler C. G. Fonstad*	
3228	Raman Scattering in the Europium Chalcogenides	R. K. Ray* J. C. Tsang* R. Aggarwal* M. S. Dresselhaus T. B. Reed	American Physical Society Meeting, Cambridge, Massachusetts, 27-29 December 1971
3229	Infrared Laser Determination of Effective Mass in GaAs-InAs Alloys	J. Waldman H. R. Fetterman P. E. Tannenwald C. M. Wolfe	
3242	Exploring Semiconductor Impurity Properties by Magnetospectroscopy of Shallow Donors	D. M. Larsen	

* Author not at Lincoln Laboratory.

SOLID STATE
DIVISION 8

I. SOLID STATE DEVICE RESEARCH

Infrared detectivity measurements have been made on InSb n-p junction photodiodes that have annular guard-ring field plates to control the surface potential at the n-p junction. At 77°K, 20-mil-diameter circular devices whose junctions were formed by proton bombardment have zero-bias resistances as high as 20 megohms at the optimum field-plate voltage, and in reduced background these diodes have detectivities as large as 2.75×10^{12} cm$\sqrt{\text{Hz}}$/W at a wavelength of 5.3 μm.

InSb p-n junction photodiodes have been fabricated by the implantation of 400-kV zinc ions into n-type crystals. For 20-mil-diameter diodes at 77°K zero-bias, resistances of 1 to 3 megohms have been observed. In reduced background, the peak detectivity of these diodes is about 10^{12} cm$\sqrt{\text{Hz}}$/W at 5.3 μm. The quantum efficiency is about 60 percent at 5.3 μm for diodes without an antireflection coating, and remains high to wavelengths as short as 1 μm.

A CW oscillator output power of 380 mW at 28 GHz with an efficiency of 6.8 percent has been achieved with an epitaxial GaAs Schottky barrier IMPATT diode having an active device diameter of 2 mils. A similar p-n junction device delivered 275 mW of CW power at 32 GHz with an efficiency of 7.8 percent. This device also produced 13 dB of small signal gain at comparable frequencies when operated as an amplifier.

Magnetic-field tuning over a range of about 2 percent of the laser energy has been observed for $PbS_{1-x}Se_x$ diode lasers at 10°K. For a $PbS_{0.82}Se_{0.18}$ diode, the laser gain spectrum was found to shift at a rate of about 0.44 cm^{-1}/kG, whereas the fine-tuning rate of an individual mode of a $PbS_{0.61}Se_{0.39}$ diode laser was about 1 MHz/kG.

Laser emission has been observed in vapor-grown $Pb_{1-x}Ge_xTe$ and $Pb_{1-x}Ge_xS$ crystals optically pumped using a GaAs diode laser source. For two different compositions of $Pb_{1-x}Ge_xTe$, the wavelengths at 10°K were 5.4 and 5.27 μm, respectively, and for a $Pb_{1-x}Ge_xS$ crystal the wavelength was 3.43 μm at 10°K and 3.33 μm at 40°K. These results suggest that the two materials are potentially useful for fabricating diode lasers throughout the 3.4- to 6.6-μm wavelength range.

II. QUANTUM ELECTRONICS

Laser emission spectra were observed from $In_xGa_{1-x}As$ and InP crystals pumped at low temperature by pulsed GaAs diode lasers. From the axial mode spacing, an effective index of refraction is found which is much larger than that observed for diode lasers of similar materials. This increase occurs because the emission frequencies of the optically pumped lasers are much closer to the band edge than are the emission frequencies of the diodes. Mode broadening occurs at high temperatures, and may be attributable to chirping caused by increased heating arising from the increased pump intensity necessary for high-temperature operation. At high temperatures, two sets of modes in InP have been observed separated by ~6Å. This corresponds to the transverse mode spacing predicted by an ~20-μm-wide guiding region.

A Q-switched YAG laser has been used to optically pump PbS_xSe_{1-x} crystals at low temperature. A single alloy composition crystal operated as a laser over a range of up to 10 percent of the center frequency. This provides a fractional tuning range comparable to a dye laser. By using several alloy compositions, laser action has been observed from 3.9 to 8.6 μm.

Three water-vapor absorption lines were studied at atmospheric pressure using a tunable PbS_xSe_{1-x} diode laser. The lines were identified and their widths, strengths, and relative positions were measured. Comparing present results with earlier work, we find that these high J lines are a factor of 2 to 4 narrower than previously estimated, the strengths agree within experimental error, and the relative line positions differ by several hundredths of a wave number.

Work continues on determining parameters of the ν_1-band of SO_2 using tunable laser spectroscopy. The intensities of several isolated lines were measured. From these data, the total band strength was found to be $358 \pm 20 \times 10^{-20}$ cm^{-1} mol^{-1} cm^2, and the effective vibrational transition moment was determined to be 0.086 ± 0.003 D.

III. MATERIALS RESEARCH

The principal features of the energy bands for transition metal TX_2 compounds crystallizing in the pyrite, marcasite, and arsenopyrite structures have been derived on the basis of symmetry arguments and the conceptual phase diagrams previously developed. The structure-determining interactions are argued to be cation-anion interactions, not cation-cation interactions. Except in the MnX_2 chalcogenides and $CrSb_2$, the 3d-electrons appear to be itinerant rather than localized, and the crystallographic determinant is not the conventional Jahn-Teller mechanism.

The growth of ZnTe crystals from the vapor phase in an open-tube system has been studied in order to determine the effect of carrier gas velocity on the degree of supersaturation required for nucleation and growth. At the lowest velocities, the difference between the temperature at which the carrier gas was saturated and the temperature required for nucleation was 20° to 30°C. With increasing velocity, the temperature difference decreased to a minimum of essentially zero at Reynolds numbers of 1000 to 2000 and then increased significantly.

Auger electron spectroscopy has been used to determine impurity profiles of 200-Å-thick gold films deposited by evaporation on Pyrex which has first been coated with a very thin layer of nichrome (Ni, Cr, Fe) or Kanthal (Fe, Cr, Al). After the gold-nichrome-Pyrex composite has been annealed at 600°C in air for 16 hours (the procedure used to obtain adhering films for transparent furnaces), the Ni and most of the Fe are found at the outer surface of the gold, while most of the Cr remains at the gold-Pyrex interface.

IV. PHYSICS OF SOLIDS

The phosphor upconversion studies have continued. In gagarinite ($NaY_{0.81}Yb_{0.18}Er_{0.01}F_4$), the excitation and emission spectra have been investigated. Also, measurements of the phosphor efficiency have been made; primary efforts have concentrated on increasing the near-infrared input intensity in an attempt to establish the upper bounds of achievable efficiency. In the ZnS phosphor program, infrared stimulation measurements on a nominally undoped ZnS indicate a behavior which is qualitatively identical to that observed in doped ZnS:Cu, Al. Preliminary solutions to the rate equations for one set of values of the various parameters indicate results qualitatively in accord with experiment.

In the high-resolution laser spectroscopy program, studies of the fundamental vibration-rotation bands of nitric oxide have now been extended to Q branches. Several lines near the head of both the $Q_{1/2}$ and $Q_{3/2}$ branches have been fully resolved for the first time; both Λ-type doubling and nuclear hyperfine structure are observed for the first few $Q_{1/2}$ absorption lines.

The frequency gain (loss) profile of several vibrational-rotational lines of a CO gas laser amplifier was measured using a tunable PbSSe laser operating near 5.3 μm. With a linewidth of <1 MHz, the current-tuned semiconductor laser completely resolves the lineshape of each individual line.

High-resolution spectra have also been obtained in methane, nitrogen dioxide, and water vapor by means of a current-tuned PbTe diode laser emitting near 6.5 μm.

The recently developed technique of obtaining submillimeter radiation from molecular gases by optically pumping with CO_2 lasers on a quasi-CW basis has been extended to the high-power regime by use of a CO_2 TEA laser (~0.7 MW). In addition to increasing the submillimeter power output, a large number of previously unreported lines were found in CH_3OH and CH_3F.

In other high-resolution infrared studies, the photoconductivity spectral response of n-type ultrapure ($\sim 2 \times 10^{10}$ donors/cm^3) germanium was investigated by Fourier spectroscopy in the range 60 to 120 cm^{-1} and at liquid helium temperatures. The spectral response appears to be due to four hydrogen-like series of transitions, two of which have been tentatively identified from earlier low-resolution studies as arising from antimony and phosphorous donors. Previously unobserved structure, due to transitions to the higher excited $p^{\pm}$ and $f^{\pm}$ levels of hydrogen-like shallow donors, has been found and identified.

The room-temperature far-infrared reflectivity of paratellurite, TeO_2, has been investigated from 50 to 400 cm^{-1} using a Fourier spectrometer. Due to the presence of optical activity, transparency from 0.33 to 6.5 μm, strongly birefringent refractive indices, an extremely slow ⟨110⟩ shear wave, and a lack of center of inversion, TeO_2 appears promising for piezoelectric, acousto-optic, and nonlinear optical applications.

The spontaneous spin-flip linewidth is an important parameter which affects the gain, threshold, and fine tuning of the spin-flip Raman laser. In an effort to understand theoretically the lineshape in n-type InSb, the effects of ionized impurity scattering at low temperatures have been derived by means of a Bethe-Salpeter transport equation. The results are similar to those obtained previously by using a phenomenological relaxation-time ansatz.

V. MICROELECTRONICS

Because of the diversified nature of the service programs, it has become customary to report on only a few of the current programs in each of the major areas within the microelectronics program. In order to provide a broader view of the overall activities, at least on an occasional basis, we have chosen to summarize all (or nearly all) our current service commitments.

The mask-making area produces about 100 masks per month, and approximately 10 to 20 masks are employed in the microelectronics programs while much of the remainder is supplied to groups involved in surface wave acoustics, LSI, and materials research. The quality of delivered masks has improved considerably as a result of an intense investigation during the last few months into the causes of mask defects. The yield of high-resolution masks continues to be low primarily because of contamination problems in the mask-making area.

Current major service programs in the semiconductor area include:

(a) Semiconductor structures for the surface wave acoustics program.

(b) Double-sided semiconductor devices for nuclear particle detectors.

(c) Photodiode arrays for the Educational Technology Program.

(d) Large silicon devices for an optoelectronics sensor program.

(e) Several types of silicon devices for the EBS (electron beam semiconductors) program.

(f) Silicon wafers with various diffusions for the LSI program.

(g) Microwave devices with special geometry.

Minor programs include:

(a) Special devices or structures for several unrelated programs.

(b) Silicon dioxide deposition for the materials research group.

(c) Assorted devices for an in-house stock of parts for hybrid programs.

Present programs in the thin-film area include:

(a) High-quality aluminum-silicon alloy film deposition on silicon wafers for the LSI program.

(b) Electron beam film evaporation in support of the surface wave acoustics program.

(c) Thin-film substrates for a 2-GHz transistor amplifier.

(d) Thin-film substrates for a 3-MHz limiter, 30-MHz limiter, feedback amplifier, and several other hybrid circuits.

(e) Preparation of transition metal oxide films for metal-insulator transition studies.

(f) Thin-film structures for microwave circulators.

In addition, the thin-film area provides routine processing of about 100 items per month.

The bonding and assembly area has fabricated about 50 prototype hybrid circuits during this quarter, apart from the assembly and packaging of devices relating to the programs listed under the semiconductor area. The bonding area also undertakes about 15 to 20 separate and special tasks per month for other groups.

The throughput time for hybrid circuits presently averages about 3 months, and at least 6 weeks of this time is the delay associated with the procurement of devices or parts from industry. When the parts are all fabricated in-house (as, for example, in the case of the photodiode array for the Educational Technology Program), the throughput time, which includes some developmental effort, is 28 days.

The research and development programs have been less active recently as a result of increased service commitments. Air-gap crossovers for monolithic integrated circuit metalization has received some attention and is being designed into a digital diode matrix. The laser scanner for testing integrated circuits is being used as a working test instrument for service programs, and no further development is planned.

DOCUMENT CONTROL DATA – R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Lincoln Laboratory, M.I.T.	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP None

3. REPORT TITLE

Advanced Electronic Technology

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Quarterly Technical Summary for 1 November 1971 through 31 January 1972

5. AUTHOR(S) *(Last name, first name, initial)*

Herlin, Melvin A. and McWhorter, Alan L.

6. REPORT DATE 15 February 1972	7a. TOTAL NO. OF PAGES 28	7b. NO. OF REFS None

8a. CONTRACT OR GRANT NO. F19628-70-C-0230 b. PROJECT NO. 649L c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) Advanced Electronic Technology QTS, 15 February 1972 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* ESD-TR-72-34

10. AVAILABILITY/LIMITATION NOTICES

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES None	12. SPONSORING MILITARY ACTIVITY Air Force Systems Command, USAF

13. ABSTRACT

This Quarterly Technical Summary covers the period 1 November 1971 through 31 January 1972. It consolidates the reports of Division 2 (Data Systems) and Division 8 (Solid State) on the Advanced Electronic Technology Program.

14. KEY WORDS

digital computers
integrated circuitry
magnetic films
computer systems
solid state devices
materials research
laser research
light scattering
power-series expansion
microelectronics

☆ U.S. GOVERNMENT PRINTING OFFICE: 1972 704-014/32